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Learning Multisensory Representations

Robert Jacobs
UNIVERSITY OF ROCHESTER

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Final Report

Air Force Research Laboratory
AF Office Of Scientific Research (AFOSR)/ RTA2
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Air Force Materiel Command

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14. ABSTRACT

People's everyday experiences are multisensory. For example, while eating breakfast, we both see and grasp our coffee cup. Moreover, multisensory perception is critical in some highly important situations, as when a TSA agent searches a passenger's bag by both looking inside the bag and touching its contents or when a police officer frisks a person using both visual and tactile inspection. In brief, our research program uses experimental and computational methodologies to study how people acquire multisensory representations and how the use of these representations influences perceptual judgements and decision making. The program focuses on people's performances in visual-haptic and visual-auditory environments. Funding from this grant supported research reported in 7 journal publications and 3 conference publications (manuscripts based on 2 of the conference publications are currently being prepared for journal submission).

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AFOSR research grant FA9550-12-1-0303: Final Report
Learning Multisensory Representations (PI: Robert Jacobs)

People's everyday experiences are multisensory. For example, while eating breakfast, we both see and grasp our coffee cup. Moreover, multisensory perception is critical in some highly important situations, as when a TSA agent searches a passenger's bag by both looking inside the bag and touching its contents or when a police officer frisks a person using both visual and tactile inspection.

In brief, our research program uses experimental and computational methodologies to study how people acquire multisensory representations and how the use of these representations influences perceptual judgements and decision making. The program focuses on people's performances in visual-haptic and visual-auditory environments. People are extraordinarily good at learning information via one sensory modality but applying the acquired knowledge when environments are perceived via a different modality, a phenomenon known as cross-modal transfer. To date, artificial intelligence systems are relatively poor at cross-modal transfer when environments are defined in a realistic manner.

People learn modality-independent, conceptual representations from modality-specific sensory signals. We hypothesize that any system that accomplishes this feat will include three components: (i) a representational language for characterizing modality-independent representations, (ii) a set of sensory-specific forward models for mapping from modality-independent representations to sensory signals, and (iii) an inference algorithm for inverting forward models—that is, an algorithm for using sensory signals to infer modality-independent representations. We have instantiated this hypothesis in computational systems in which the modality-independent representations are based on a probabilistic approach (distributed representations over latent variables) and in systems in which these representations are based on a probabilistic/symbolic hybrid approach (probabilistic grammars). We have also collected experimental data from people, and used our computational models to account for the experimental findings.

Funding from this grant supported research reported in 7 journal publications and 3 conference publications (manuscripts based on 2 of the conference publications are currently being prepared for journal submission).

Publications funded by this grant:

Orhan, A. E. & Jacobs, R. A. (2013). A probabilistic clustering theory of the organization of visual short-term memory. *Psychological Review, 120*, 297-328.

Yildirim, I. & Jacobs, R. A. (2013). Transfer of object category knowledge across visual and haptic modalities: Experimental and computational studies. *Cognition, 126*, 135-148.

Erdogan, G., Yildirim, I., & Jacobs, R. A. (2014). Transfer of object shape knowledge across visual and haptic modalities. *Proceedings of the Thirty-Sixth Annual Conference of the Cognitive Science Society*.

Orhan, A. E. & Jacobs, R. A. (2014). Toward ecologically realistic theories in visual short-term memory research. *Attention, Perception, & Psychophysics, 76*, 2158-2170.

Orhan, A. E., Sims, C. R., Jacobs, R. A., & Knill, D. C. (2014). The adaptive nature of visual working memory. *Current Directions in Psychological Science, 23*, 164-170.

Erdogan, G., Yildirim, I., & Jacobs, R. A. (2015). From sensory signals to modality-independent conceptual representations: A probabilistic language of thought approach. *PLoS Computational Biology, 11(11)*, e1004610.

Yildirim, I. & Jacobs, R. A. (2015). Learning multisensory representations for auditory-visual transfer of sequence category knowledge: A probabilistic language of thought approach. *Psychonomic Bulletin and Review, 22*, 673-686.

Erdogan, G., Chen, Q., Garcea, F. E., Mahon, B. Z., & Jacobs, R. A. (2016). Multisensory part-based representations of objects in human lateral occipital cortex. *Journal of Cognitive Neuroscience, 28*, 869-881.

Erdogan, G. & Jacobs, R. A. (2016). A 3D shape inference model matches human visual object similarity judgments better than deep convolutional neural networks. *Proceedings of the Thirty-Eighth Annual Conference of the Cognitive Science Society*.

Overlan, M. C., Jacobs, R. A., & Piantadosi, S. T. (2016). A hierarchical language-of-thought model of human visual concept learning. *Proceedings of the Thirty-Eighth Annual Conference of the Cognitive Science Society*.

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Robert Jacobs

Program Manager

The AFOSR Program Manager currently assigned to the award

Dr. James Lawton

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Abstract

People's everyday experiences are multisensory. For example, while eating breakfast, we both see and grasp our coffee cup. Moreover, multisensory perception is critical in some highly important situations, as when a TSA agent searches a passenger's bag by both looking inside the bag and touching its contents or when a police officer frisks a person using both visual and tactile inspection.

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